

Integrated Care for Multisensory Injury

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In 1994, the National Football League initiated a research endeavor to address problems associated with head injuries sustained by professional athletes. This ongoing study tracks the incidence, biomechanics, and recovery outcomes of

head injuries suffered by players.¹ Brain injury has also become a pressing concern in the US military, primarily due to blast-related traumas that have occurred during Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF).

Reports estimate mild traumatic brain injuries (mTBIs) after blast exposure account for 85% of all battlefield injuries.² Between 2003 and 2009, nearly one-third of US service members wounded in combat and evacuated to the Walter Reed Army Medical Center were diagnosed with TBI.² In a military cohort of immediate evacuees sustaining body-wide injuries, TBI incidence was 54%, with 14% of TBI incidences documented by abnormal neuroimaging.³ In this analysis, a higher Injury

Severity Score (ISS) was significantly associated with abnormal neuroimaging, longer hospitalization, and more severe brain injury.³ These data demonstrate the high prevalence of TBI, its typical invisible nature, and the higher probability of diagnosing structural abnormalities as non-neurologic injuries worsen.

Although TBI is recognized as the signature injury of recent military conflicts and has been the subject of media attention due to its incidence in contact sports, our understanding of TBI across the continuum of care is still limited. TBI often affects numerous brain systems, causing sensorineural deficits with or without any physical damage to peripheral sensory organs and systems. Repeat head injuries, in particular,

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may lead to chronic encephalopathy. Appropriate TBI diagnosis and treatment remains elusive, however, and is complicated by injury type (blast/non-blast, penetrating, etc) and injury severity (mild, moderate, severe).

Variables affecting neurologic systems including those involved in cognition, metabolic, and circulatory processes, and other comorbid factors can also confound TBI diagnostic test interpretations, resulting in misdiagnoses and inadequate treatment strategies. Further, identifiable organic causes of disorder are often not evident by imaging, especially for mild to moderate TBI.⁴ Unrecognized sensory system injury may preclude an accurate initial assessment of brain function, which relies on input and feedback from the senses. In an austere environment, delays in the evaluation of TBI and other non-life-threatening injuries, including multisensory injuries, may be postponed due to the precedence of managing life-threatening injuries that require airway stabilization and bleeding control.

Delays in TBI and sensory system evaluation past the acute stage of injury may result in an increased degradation of sensory systems and possible chronic sequelae, including neuropsychiatric and neurodegenerative comorbidities⁵ as a result of any delayed administration of function-preserving interventions.

Although it is an important step forward to recognize the complexities of polytraumatic injury, there is a lack of understanding concerning the interrelationships between TBI, sensory system dysfunction, pain, and psychological health. Thus, an integrated approach to polytraumatic injury research and clinical care is needed.

MULTISENSORY INJURIES AND TBI

Damage to sensory-specific areas of the brain exerts numerous distal effects, including altered multisensory experiences and diminished ability to combine sensory information.⁶ Data suggest that 44% to 62% of TBI patients report hearing loss, with 18% to 38% of these patients also

experiencing tinnitus.⁷ Further, dizziness has been reported in 98% of patients seen within 72 hours of an mTBI, and vertigo in 47% of patients seen 4 to 30 days after the primary trauma.⁸ This same study further demonstrated chronic effects of mTBI, with 84% of patients experiencing dizziness on assessment at 30 to 360 days after

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the injury. With respect to vision, following a retrospective medical record review, Stelmack and colleagues⁹ found that up to 75% of patients with TBI also experienced visual dysfunction.

Although multisensory injuries typically manifest as physical dysfunction and scarring, they are also associated with neurobehavioral and psychopathological dysfunction. For example, posttraumatic stress disorder (PTSD) and depression are strongly correlated with reported multisensory impairment.¹⁰ Thirty-four percent of patients who experienced tinnitus also had a diagnosis of PTSD; their tinnitus severity worsened with PTSD-related anxiety.¹⁰

Such bi-directional relationships also exist with other disorders and sensory systems, such as PTSD and pain.^{11,12} Though psychological assessments are not routine in non-TBI polytrauma, polytrauma patients often exhibit neurobehavioral and psychopathological disorders that require consideration and support.^{13,14}

IMPACT ON PSYCHIATRIC CARE

Auditory system injuries may not be fully recognized or appreciated by a patient or his/her health care provider but can interfere with a patient's ability to engage in a standard neurological evaluation. Strained communication can lead to miscommunication, misunderstanding, delayed diagno-

sis, misdiagnosis, and delayed or inappropriate therapy. Communication difficulty can also introduce stress and frustration that compounds physiologic responses and diminishes a patient's resolve.

Patients who feel helpless and uninformed may experience increased anxiety, depression, and isolation. These responses can manifest physically as hypertension, dizziness, gastrointestinal distress, and headache. In short, patients with undiagnosed auditory deficits are vulnerable to a cascade of additional difficulties that further confuse the clinical picture and may lead to unhelpful medication, self-medication, and potential side effects.

Auditory injury can impair psychiatric evaluation in nearly every component of a mental status exam. For example, auditory system damage that disrupts the speech-motor feedback loop can elicit a Lombard effect in which the speaker involuntarily modifies speech rate, volume, and rhythm characteristics.^{15,16} Individuals with hearing loss may incorrectly perceive aggression from a speaker who is trying to accommodate by speaking more loudly. Hearing loss often manifests as requests to repeat instructions; this may be misinterpreted as cognitive or mental dysfunction. Patterns and characteristics of speech and communication are often noted on psychiatric examination. It is important to recognize that speech and communication may be altered solely by neurosensory injury.

Multiple sensory system injuries and chronic effects may also alter a patient's general appearance and behavior (eg, motor movements, agitation), affect (blunted due to lack of engagement), sensorium, intellect, insight, and judgment (from injury sequelae such as tinnitus, persistent central processing dysfunction, and/or cognitive deficits).

Central compensation for multiple neurosensory impairments can be mentally and physically fatiguing, leading in turn to decreased interest and ability in former activities and hobbies, which can compound depression and anxiety. Patients

may also find it burdensome to manage various assistive devices, medications, and prostheses.

Another important challenge is the need for coordination among specialists. A patient who presents with TBI, PTSD, and vertigo, for example, will need to see multiple specialists for assessment and therapy. Therapy for vertigo may exacerbate TBI-related symptoms of fatigue, inattention, and memory deficits. Likewise, strategies for treating PTSD, such as exposure therapy, may exhaust the patient's mental resources, induce stress and fatigue, and thus compromise cognitive or vestibular therapy. Uncoordinated treatment regimens may leave a patient feeling helpless, finding that progress toward recovery in one domain can cause increased difficulty in another.

Likewise, assistive devices and exercises that speed recovery and rehabilitation for patients with single sensory injuries can be difficult for polytrauma/TBI patients to manage without frustration and fatigue. For example, an upper extremity amputee who also suffers from blast-related vision and hearing dysfunction and mTBI may not have the manual dexterity required to change the battery in a hearing aid, secure prostheses, or manage remote control devices. The cumulative effect of polytrauma on an already burdened physical, cognitive, and psycho-social human system is likely far greater than the sum of its multiple underlying injuries.

Although multiple providers may strive to coordinate and be aware of strained patient tolerance, a shortage of alternative strategies limits potential for individualized holistic care. Optimal outcomes are best achieved through dedicated collaboration and transparent teamwork, and by recognizing that multiple sources of disorder and dysfunction exist around intricate neural networks within the same skull space.

MILITARY MODELS OF INTEGRATED TBI CARE

Transparent, interactive holistic care and combined research of multisensory

polytrauma holds the potential to improve outcomes based on integrated and efficient management of resources. Although military environments often present unique challenges for health care, treatment approaches developed at military health care and research facilities can often be applied to civilian wellness. Readiness, population health, operational medicine, mass

Central compensation for multiple neurosensory impairments can be mentally and physically fatiguing.

casualty care, patient transport, and networked care are aspects and strategies of military health care and research not easily replicated in civilian care networks, but they can nonetheless provide experience and modeling informative to sports medicine, first responders, homeland security and other law enforcement, anti-terror, anti-narcotic, and public safety sectors of care where individuals encounter similar occupational hazards. New Department of Defense (DoD) models and systems of care are converging to overcome gaps and, where feasible, to synergize the benefits of collaborative research and care. Other programs such as the Department of Veterans Affairs' (VA) Polytrauma System of Care are addressing acute long-term polytraumatic injury care and rehabilitation with a concerted focus by clinical support teams.

Between 2000 and 2011, TBI manifested as a predominant wound of war. During this period, 355,425 cases of military TBI were diagnosed, 13% of which were moderate, severe, or penetrating.¹² The Defense Center of Excellence (DCoE), the Defense and Veterans Brain Injury Center (DVBIC), the Joint Theater Trauma System (JTTS), and the Committee on Tactical Combat Casualty Care (CoTCCC) have been established to oversee and improve outcomes of TBI. In partnership with the DoD, privately

raised funds from the Intrepid Fallen Heroes Fund (IFHF) constructed the National Intrepid Center of Excellence (NICoE), which is committed to providing interdisciplinary diagnostic evaluations and treatment of complex TBI and psychological health conditions. Programmatic research is now focused keenly on defining the injury and improving our ability to diagnose, treat, and rehabilitate TBI.

To further address gaps in our knowledge of polytrauma, Public Law 110-417 Duncan Hunter National Defense Authorization Act (NDAA 2008/9) established the Vision (VCE), Hearing (HCE), and Extremity Trauma and Amputation (EACE) Centers of Excellence (CoEs), which focus on the prevention, diagnosis, mitigation, treatment, and/or rehabilitation of traumatic injuries.

The CoEs' missions include ensuring broad collaboration to develop data exchange platforms, encourage and facilitate research, develop best practices, and improve clinical education. With shared patients and overlapping interests, a natural partnership has developed among the CoEs to provide biomedically validated, scientifically repeatable, and data-driven solutions. Another joint DoD/VA organization with domain and interest overlap in polytrauma is the Defense and Veterans Center for Integrative Pain Management (DVCIPM), established to improve pain management in military and civilian medicine.

The DoD CoEs have developed a consortium to address many of the unknown facts and factors in multisensory polytrauma diagnosis, treatment, and rehabilitation. Informally known as the Allied NeuroSensory Warrior Related Research (ANSW2R), this consortium effort engages experts from multiple disciplines and domains to address the need for new models of neurosensory polytrauma research and treatment. ANSW2R aims to support a more comprehensive understanding of neurophysiological trauma, including the chronic sequelae associated with multisensory polytrauma.

The US Army Medical Research and Materiel Command's (USAMRMC) Clinical and Rehabilitative Medicine Research Program (CRM RP) also recognizes the complex needs of service members with polytraumatic injuries. Pursuant to guidance from DoD senior leadership, the CRM RP seeks to restore warfighter-level functional capabilities and improve injured service members' quality of life.

The CRM RP works with the CoEs to identify critical research and clinical capability gaps that must be filled to address the needs of service members with polytraumatic injuries. The research and clinical capability gaps identified include those that target polytrauma-related sensory system dysfunction and pain, including biopsychosocial aspects (psychological health, sleep, nutrition, family and social dynamics, vulnerability and resiliency).

Given the complexity of polytraumatic injuries, the CRM RP allocates resources to gain a better understanding of and improved treatments for sensory system dysfunction and pain as related to polytrauma.

The CRM RP, in conjunction with the DoD Office of the Assistant Secretary of Defense for Health Affairs, the VA, and other USAMRMC Research Area Directorates, is establishing a joint DoD/VA consortium to investigate the chronic effects of neurotrauma, specifically mTBI. This consortium effort is dedicated to establishing a comprehensive understanding of the chronic sequelae associated with mTBI, including the identification and characterization of underlying mechanisms and comorbidities including sensory dysfunction, pain, and psychological health. The consortium will also identify and evaluate diagnostic indicators of mTBI-induced comorbidities and develop therapeutic strategies to treat and rehabilitate patients who experience sensory system dysfunction, pain, and psychological health issues associated with mTBI.

These efforts will provide invaluable knowledge of the incidences and mechanisms of comorbid conditions associated

with combat- and civilian-related mTBI. This information will translate to veteran and civilian populations through improved clinical diagnoses and definitive therapies for mTBI and related sequelae. The integration of preventive, protective, rescue, and rehabilitative strategies will add value to nonmilitary environments, settings, and occupations where individuals are exposed to similar injury scenarios.

CONCLUSION

There is a pressing need to develop an integrated approach to research, diagnosis, treatment, and rehabilitation of polytrauma. The CRM RP and DoD/VA CoEs recognize this need and continue to assess, fund, and translate the best research available to elevate care, outcomes, and quality of life for service members, veterans, and ultimately for all citizens.

An integrated approach is especially critical to understand and address the complexities among multisensory injuries and their effects on patient evaluation and treatment. To meet this goal, effective collaboration among experts across multiple relevant disciplines and domains (government/military, academia, and private industry) is necessary as is an integrated system-of-systems approach to the ongoing study, treatment, and rehabilitation of multisensory injury.

The initiatives and activities noted herein describe efforts to bring scientifically grounded knowledge to the patient bedside through translational development of diagnostic tools, treatment regimens, and rehabilitation strategies with the ultimate goal of improving health and quality of life after TBI.

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